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THIN WALL FOUNDATION

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FOREWORD

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EXECUTIVE SUMMARY

The objective of this project was to study the feasibility of building residential basement foundation walls of unreinforced concrete thinner than the conventional 200 mm thick wall. The "thinwall" foundation should require no special engineering attention, and should be acceptable as a standard to the industry.

Project work comprised a literature search, building code review, and a feasibility analysis which included technical and cost considerations. Additionally, an industry perspective was obtained through interviews with house builders and contractors specializing in residential basement work.

Key issues were determined to be strength, quality control, construction methods and tolerances, cost savings and market acceptance. As thickness decreases, strength is sacrificed, and the negative effect of axial eccentricity increases, particularly for a foundation wall supporting brick veneer. Quality control, particularly in respect of concrete strength and water/cement ratios, is important from the perspective of maintaining bending capacities. Some construction methods, for example cast-in-place joists or the use of nailing ladders, make pouring concrete more difficult in thinner walls. Cost savings and market acceptance are linked and though cost can be reduced, it may be difficult to influence buyers to break from the traditional 200 mm wall in favour of a thinner one.

Consideration of the issues led to the determination of 150 mm as the optimum reduced thickness for an unreinforced 2,400 mm high foundation wall. A basement wall of 150 mm thickness and 20 MPa concrete strength supporting a house with brick veneer would be capable of retaining 1,500 mm of backfill material. The same wall supporting a house without brick veneer would be capable of retaining 1,800 mm of backfill. The cost of the 150 mm thick wall would be in the order of $600 less than that of the conventional 200 mm wall, and those savings could be passed on to the consumer.

Technical analysis was based on equivalent fluid pressures and indicated that the 150 mm foundation wall would be suitable for use with

sand and gravel backfill material. For walls backfilled with soils other than clean sand and gravel, it was found that the theoretical maximum backfill heights for both 150 mm and 200 mm walls are substantially less than those presently specified by Table 9.15.4.A of the Alberta Building Code. The practice of backfilling with stable native soils (which are characterized by significantly higher equivalent fluid pressures) is common and house foundations have performed well under those conditions. The study therefore concluded that either the accepted values for equivalent fluid pressures or the assumed triangular distribution of lateral soil pressures are in question.

To further investigate lateral pressures from different types of soils, a testing program was recommended. In addition to providing valuable information in support of soil pressure design assumptions, the testing program would verify the performance of the thin wall foundation, to assist in transferring the technology to the marketplace.

1.0 INTRODUCTION

Common practice in the construction of single family detached dwellings incorporates 200 mm (8") thick basement foundation walls. The objectives of this project were to determine, from the technical, economic, practical and jurisdictional perspectives, the feasibility of building thinner foundation walls, and to determine a thickness considered optimum within the scope of those parameters.

In 1989, approximately 11,600 single family detached dwellings were built in Alberta. The vast majority of those included 200 mm foundation walls. On the provincial scale, cost savings to home purchasers resulting from thinner foundation walls could be quite significant. Potential cost savings, however, must be considered in concert with and validated by the remaining parameters noted above.

The work of the project focused on unreinforced concrete walls, with concrete strengths of 14 MPa and 20 MPa. Reinforced concrete walls were also investigated for purpose of comparison. As a governing condition, a clear height of 2,440 mm (8') from top of slab to underside of floor joists was required for all wall thicknesses considered.

A literature search was undertaken to determine the state-of-the-art in thin wall foundation walls. Canadian building codes and standards were reviewed for relevant clauses. Certification procedures to accept new clauses into the Alberta Building Code were examined. A feasibility analysis addressing technical, practical and economic issues was undertaken and an optimum thickness was determined. To validate the performance of thin walls, a testing program was developed for future consideration.

2.0 LITERATURE SEARCH

Two data bases, the Engineering Index and the National Technical Information Service were searched. No information relevant to the project objectives was found.

The libraries of both the Canadian Home Builder's Association and the National Association of Home Builders were searched. Many papers were found relating to foundation walls, including some design information. However, nothing specific to thin walls was found.

Canada Mortgage and Housing, and the Canadian Portland Cement Association could not provide any information relating to thin wall foundations.

A related unpublished study on soil pressure against steel wall foundations in Regina, Saskatchewan was found. This work was performed by the National Research Council (NRC) of Canada. Pressure on steel walls was measured using pressure cells mounted on the face of the walls. This data had not been published because it was not considered reliable due to some oversights during the testing. Pressure cells were not calibrated and the test data has not produced any conclusions. The other significant factor is that these steel walls were substantially less stiff than concrete walls and would result in a different lateral pressure coefficient.

Literature on wood foundation walls was also reviewed. Although the materials and stiffness of construction differ from concrete foundation, useful information was found concerning soil pressures. This information corroborated calculations developed by this project.

In summary, no other relevant research information was found.

3.0 BUILDING CODE REVIEW AND ANALYSIS

Section 9 of the Alberta Building Code (ABC) covers specifications for standard house construction. Figure 1 illustrates some of these specifications for a typical basement foundation wall. For example, a minimum backfill height of 1.2 m to a maximum height of 150 mm below the top of the wall is specified. These are practical limits applying to protection from frost and drainage.

Figure 2 (Table 9.15.4.A ABC) gives permissible backfill heights for 150, 200, 250 and 300 mm thick walls with concrete strengths of 14 MPa and 20 MPa, and indicates that walls less than 200 mm are permitted by the National Building Code and the Alberta Building Code.

The predecessor to Table 9.15.4.A is shown in Figure 3. This table is for 2,000 psi concrete and is the same as Table 9.15.4.A for 14 MPa concrete. An interesting observation is that the design assumptions in Table 9.15.4.A have not changed since Table IX was published by the NRC in the 1962 Housing Standard. A copy of a letter uncovered at the NRC states that Table IX is based on a soil pressure equivalent to a liquid density of 30 pounds per cubic foot (480 kg/m^3).

Concrete standard CAN3-A23.3 M84, "Design of Concrete Structures for Buildings", § 22.4.1.6.3, states that exterior basement walls shall not be less than 190 mm thick. This correctly applies for a 2440 m high wall supporting a 'standard' two storey house with brick veneer, defined by Table 3, and backfilled with a soil that has a equivalent fluid density of 480 kg/m^3 to a height of 2,100 mm, but it does not allow for lesser loading conditions as considered by the National and Alberta Building Codes and this report.

CAN3-086.1-M84, "Engineering Design in Wood (Limit States Design)" specifies soil pressures, as equivalent fluid densities, that are to be considered in the design of wood foundation walls. Recommended pressures range from 480 kg/m^3 for clean sand and gravel to 1,600 kg/m^3 for soft silt and clays and are used for reference purposes in this report.

4.0 CERTIFICATION

If proposed walls do not meet the Alberta Building Code, particularly Table 9.15.4.A, a request to change or add clauses in the Alberta Building Code may be accomplished in two ways. One approach is through an inspector or the Director of Alberta Building Standards; the other is through the minister responsible for of Building Standards. In both cases the evidence required may be in any form seen fit by the party seeking certification. The evidence may be tests, calculations, in-situ examples and petitions from interested parties.

Using the first approach, the evidence is given to either an inspector or the director of Building Standards. They will in turn make a ruling on the request by whatever method they see fit. They may seek professional advice, comments from the industry or base the decision on their own judgement. If the ruling is in favour of the request a Director's Ruling, Director's Interpretation, or Standata Document is appended to the Alberta Building Code.

In the second approach, which applies to major code changes, the evidence is presented to the Minister responsible. The Minister passes the request to cabinet who will ask advice from Building Standards and arrange for a public hearing. The results from the public hearing and the advice from Building Standards are returned to the Minister for a final decision. If the decision is in favour, the request is deemed as law and would appear in the next edition of the Alberta Building Code which is updated every 5 years.

5.0 FEASIBILITY ANALYSIS

5.1 Technical Considerations

Factors governing technical design were backfill type and height, vertical loading, eccentricity of loads and slenderness effects. Figure 4 illustrates the design model used. Three loads are shown; the axial load, P_A, due to wall loads applied to the top of the foundation, the vertical load, P_B, caused by brick facing, and the lateral soil pressure, W. An axial load eccentricity, e, was assumed to be 25 mm for all wall thicknesses studied. The centreline of the load for brick facade was taken to be 75 mm from the outside face of the foundation wall. Lateral soil pressures from three types of soils were considered and are listed and described in Figure 6. Section 9 in the Alberta Building Code specifies a minimum design soil pressure, 480 kg/m^3 corresponding to type 1 soil (clean sand and gravel) used in this report. In a letter obtained from the NRC it is stated that the Committee is not aware of any failures of foundation walls due to lateral soil pressures. Although it is understood that, for the most part, basement foundation walls are backfilled with native material and very rarely clean sand and gravel, a limiting design criteria for soil pressure of 480 kg/m^3 fluid density is used in this report.

Shown in Figure 5 are interaction diagrams for five thicknesses of unreinforced concrete walls. The axial resistance (defined as the factored maximum compressive load the wall can carry) versus the moment resistance (defined as the factored maximum bending moment a wall can carry) is given for a 100, 125, 150, 175 and 200 mm wall with a concrete strength of 14 MPa. The shape of these curves are distinct, composed of two intersecting lines of opposite slope. The two lines reflect that concrete is stronger in compression than tension. The upper line (negative slope) represents the condition when the wall is under high compressive load, caused by the weight of a building structure, combined with bending, caused by the soil leaning against the wall. As a result, the wall fails on the compressive face (outside face of the wall) by crushing. The lower line (positive slope) represents the condition when the wall is under low or no compressive load combined with bending. The wall therefore fails on the

tension face (inside face of wall) in a cracking manner. The point where the two lines intersect represents the compressive and bending loads at which the wall fails in compression and tension simultaneously. These two lines are calculated via clause 22.3.3.6 of CAN3-A23.3-M84, 'Design of Concrete Structures for Buildings'.

A range of axial loads on a basement foundation wall is shown on the vertical axis of Figure 5. The normal range of 47.7 kN was calculated from a 'standard' 2-storey house with brick veneer using data from Table 3 multiplied by a dead load factor of 1.25 and a live load factor of 1.5. This illustrates that failure always occurs by cracking on the inside face of the basement wall.

Figure 5 is also an aid in selecting one of the governing loading conditions, of which there are two. The first occurs when the axial load acts within the middle third (kern) of the foundation wall. Figure 5 illustrates that within the range of normal axial loads, 0 to 47.7 kN, the capacity of the wall to resist lateral loads from soil increases. Therefore the governing loading condition is full soil pressure and no axial load. The second governing loading condition occurs when the axial load acts outside of the kern causing additional tensile stresses on the inside face of the wall. This occurs for walls less than 150 mm not supporting brick and for all walls supporting brick veneer. For this case, the governing loading condition is full axial load plus full soil pressure.

Figures 6 and 7 show graphs of factored moments (defined as the working moments multiplied by a live load factor of 1.5) as a function of backfill heights for three types of soil acting against a 2,440 mm high wall. Superimposed on both graphs are the lateral moment resistance for five wall thicknesses. The lateral moment resistance (defined as the ultimate moment multiplied by a material factor of 0.6) given in Figure 6 and 7 represents the two governing loading conditions, covered by considering a 'standard' 2 -storey house without brick veneer, and a 'standard' 2-storey house with brick veneer.

The lateral moment resistance in Figure 6 is calculated for a wall with no axial load, for example the basement is backfilled (floor joists in place) before

the superstructure is built, and is equal to M_0 (Figure 5). For houses without brick and wall thicknesses 150 mm or greater the maximum height of backfill is shown in Figure 6 and is calculated for a wall with no axial load because any axial loads act within the kern increasing the bending capacity. For walls thinner than 150 mm, axial loads may act outside of the kern reducing the bending capacity. This effect is shown by the vertically drawn dotted lines in Figure 6. The reduction is due to a fully loaded 2-storey house with no brick veneer.

In Figure 7 the lateral moment resistance (LM_R) is calculated for a 2-storey house with brick veneer: $LM_R = M_R - (P_A + P_B)\, e\delta_b$. The first term, M_R, is obtained from Figure 5 and includes an increase in bending capacity from the axial load. The second term is a reduction from eccentricity and slenderness effects. The slenderness constant δ_b varies from 1.03 for 100 mm walls to 1.005 for 200 mm walls affecting the bending performance in a minor way.

The horizontal lines plotted on Figure 6 and 7 show the maximum allowable backfill heights for a 150 mm and 200 mm wall given by Table 9.15.4.A, Alberta Building Code. The intersection of these lines with corresponding lateral moment resistance curves gives the theoretical soil pressure the wall can resist. In Figure 6 these values (shown by circles) fall within the code minimum design soil pressure. In Figure 7 these values lie slightly outside of the minimum design soil pressure curve.

5.2 Cost Analysis

A subcontract was awarded to Helyar and Associates to study the potential for cost savings by building thin foundation walls. Costs were grouped into three categories: excavation, concrete, and dampproofing. Excavation includes backfill, sand or gravel under the floor slab, a vapour barrier, and removal of surplus excavation material. The concrete category includes footings, wall reinforcing steel (2-15 M top and bottom of wall), 12 mm anchor bolts for a wood sill, 3 inch floor slab, and parging. Dampproofing included two coats of asphaltic emulsion on the outside face of foundation wall and 100 mm diameter weeping tile with crushed stone filter.

Estimates were made for two house sizes, 'small' (9.6 m x 8.4 m) and 'standard' (9.6 m x 12 m) using either 15 MPa or 20 MPa concrete in 125, 150, 175 and 200 mm thick walls. Eight locations in Alberta were considered: Edmonton, Calgary, Peace River, Fort McMurray, Grande Prairie, High Level, Lethbridge and Lloydminster. A comparative cost table is included in Appendix A.

The largest savings occur in the remote locations, where the unit price of concrete is greatest and coincidently the foundation costs are also greatest. Shown in Table 4 is a summary of highest, lowest and average cost savings for complete foundations with 15/125 (15 MPa/125 mm thick) and 20/150 walls compared to 20/200 walls. Figure 8 shows cost comparisons between 20/150 and 20/200 walls for eight locations. Costs are compared to a 'standard' 200 mm wall foundation in Edmonton (Edmonton = 1.0).

5.3 Reinforcement

For thin walls to equal the strength performance of a 200 mm unreinforced wall reinforcing would be required.

Two methods of reinforcement were considered, deformed reinforcement and fibre reinforcement. Neither method appears feasible. Table 2 specifies the reinforcing necessary for 100, 125, 150 and 175 mm walls to equal the performance of a 200 mm unreinforced wall. The cost to supply and install reinforcing steel offsets approximately half the savings in concrete. An inspection would be required to ensure the reinforcing is properly placed. The cost of this inspection plus supply and installation would offset any savings in concrete. For fibre reinforcements, to obtain strength gains beyond the tensile capacity of concrete a large volume of fibres are required, approximately 2% to 3% by volume of concrete. Costs for fibre reinforcement are prohibitive and are in the order of $\$300/m^3$ Placement problems also arise when large quantities of fibres are used. A reinforced option is not recommended or necessary because the additional costs of reinforcement more than offset any gains attributable to the thin walls.

5.4 Industry Perspective and Impact

Interviews with a reputable cribber and other contacts in the house building industry revealed the following concerns regarding thin wall foundations.

1. Quality Control

Poor quality control on residential construction sites will have greater impact on thinner walls. For example, 15 MPa concrete with a 100 mm slump may be specified but, on site, water is usually added to increase the slump to as much as 175 mm. A standard 200 mm wall would absorb this inconsistency better than a thinner wall.

Construction tolerances on walls can vary up to 25 mm, consuming a larger percent of the total thickness as walls get thinner. This has a greater effect on bending capacity (varying with the square of the wall thickness).

The time of placement of backfill will also affect thinner walls. More curing time would be required in order to ensure a wall reaches sufficient strength to withstand forces imposed by backfilling.

2. Construction Methods

The practice of cast-in-place wood joists and nailing ladders which remain after the forms are stripped makes the opening at the top of the wall smaller. For example, a 150 mm wall with a nailing ladder leaves a 75 mm void to pour concrete through; this probably represents a limit for pouring concrete. Anchor bolts rather than nailing ladders would be recommended for walls thinner than 150 mm.

3. Concrete Suppliers

A standard house built using a 20/150 wall saves approximately 5 m^3 of concrete compared to a 20/200 wall. In Alberta from 1977 to 1987 the average yearly number of detached housing starts was approximately 14,000. At concrete costs of \$90 - \$110/m^3 a reduction from 200 mm to 150 mm would represent lost revenue to concrete suppliers, depending on market penetration.

4. Market Acceptance

The average homebuyer may be less inclined to buy a thin wall foundation house because it is not the norm. Buyers may ask for performance guarantees in addition to the expected cost savings.

5. Builder Acceptance

It is generally felt that builders would not resist thin foundation walls. They would build whatever the market demands provided the walls are technically sound.

6. Conservation

Portland Cement is an energy extensive product. To produce a kilogram of portland cement can require on the order of 7.0 MJ of energy. A cubic metre of 20 MPa concrete requires approximately 260 kg of portland cement. Saving 5 m^3 of concrete per house for 14,000 houses would save 127,000 GJ of energy of portland cement production. This represents about 20,000 barrels of oil; or it is approximately equal to the amount of energy 400 people consume in one year. These values are energy savings in the production of portland cement only and do not include savings associated with the supply and mixing of aggregate, water and cement to produce concrete.

6.0 OPTIMUM WALL THICKNESS

Parameters governing optimum wall thickness are both quantitative and qualitative.

The quantitative parameters are cost, quality control and construction tolerances. Reinforcing thin walls is ruled out because the cost of reinforcing offsets any savings in concrete.

There is a cost associated with educating the public on thin wall foundations, and this cost is difficult to quantify. For walls thinner than 150 mm a one time cost would be incurred in order to affect code changes through Alberta Building Standards.

An appreciation for the effect of quality control and construction tolerances may be gained by examining Figures 6 and 7. It can be seen that the performance of a wall varies with the strength and thickness of the concrete. Walls less than 150 mm become affected by eccentricities and would be further aggravated by variations in wall thickness.

The qualitative parameter is market acceptance. Builders would construct thin wall foundations if the market so desired. Besides education, the homebuyers would probably want some performance assurance for using thin wall foundations. Currently the Alberta Building Code allows 150 mm walls.

In view of the above considerations an optimal unreinforced concrete wall thickness of 150 mm is recommended. Maximum backfill heights are 1,800 mm without brick veneer, and 1,500 mm for walls supporting brick veneer.

7.0 COST SAVINGS

The cost savings in building a 20/150 compared to a 20/200 foundation wall vary with location. From the cost study for the eight locations across Alberta, the average total cost of constructing a 'standard' 20/200 house basement is $11,581, which includes 10% overhead and 10% profit. The average savings that would result from constructing a 150 mm foundation wall rather than a 200 mm wall is $642 for a 'standard' house which represents 5.6% of the cost of the basement. The largest saving, $763 (6.3%), occurs in Grande Prairie; the smallest saving, $502 (4.6%), occurs in Calgary. It can be expected that savings in the order of $600 may be passed onto the consumer as a result of replacing 200 mm foundation walls with 150 mm foundation walls.

8.0 PHYSICAL TESTING PLAN

Figures 6 and 7 show the depth of soil against foundation walls and the resulting moment. The lateral moment resistance of walls 100, 125, 150, 175 and 200 mm thicknesses is superimposed in order to show the limits of backfill for three types of soils.

Two major parameters shown in these figures are:

1. Moment resistance of unreinforced concrete walls.
2. Soil pressure.

The moment resistance is based on geometrical section properties and the rupture modulus of concrete (a function of the compressive strength). Compressive strength may be accurately determined from cylinder tests. Therefore, moment resistance of unreinforced concrete walls can be determined with a high degree of confidence.

Soil pressure cannot be ascertained with a high level of confidence. The soil pressure curves in Figure 6 and 7 are based on equivalent fluid densities adapted from the Canadian Foundation Engineering Manual, March 1971 ("Engineering Design in Wood" CAN 3 086 M84 also has adopted these values for the design of wood foundations). The equivalent fluid densities in the Canadian Foundation Engineering Manual are based on "Soil Mechanics in Engineering Practice" by Terzaghi and Peck, 1948. This reference states that the equivalent fluid method is an approximate design procedure based on both empirical and semi-empirical methods for estimating pressures of backfill.

Soil pressure is the parameter that requies confirmation by testing. A test wall arrangement is shown in Figure 7. Pressure cells and dial gauges would be used to measure soil pressure and lateral movement respectively.

Tests could be performed on a 6.0 m long by 2.44 m high section of foundation wall or on a full size house foundation. A specially built facility is most desirable so that different soil types could be tested and measurements taken over a period which would include seasonal moisture changes and

frost action. A full size house foundation would also be desirable because each of the four walls could be loaded simultaneously with different soil and soil conditions.

9.0 CONCLUSIONS

Thin wall house foundations are a viable alternative to the standard 200 mm walls. Savings in the order of $600 per foundation can be attained. The Alberta Building Code permits the use of a thin wall (150 mm). Notwithstanding its acceptability under the code, user acceptance is expected to be a problem.

Largely based on practical considerations the optimum wall thickness was found to be 150 mm. This is subject to limitations regarding soil types, concrete strength, exterior veneer and the size of the house.

Lateral pressure from different types of soils is the parameter that requires further investigation. For walls backfilled with soils other than clean sand and gravels, the theoretical maximum backfill height for a 150 mm and 200 mm wall is substantially less than those specified by Table 9.15.4.A of the Alberta Building Code, particularly for a house with brick veneer. The practice of backfilling with stiff stable soils such as type 2 soils is common. Historically, house foundation walls perform well under these conditions. Therefore either the equivalent fluid pressure or the triangular pressure distribution are in question.

A testing program is recommended to support the design assumptions, and would assure users that thin wall foundations will provide a safe and acceptable performance.

Table 1. List of Symbols

h	=	thickness of wall
L	=	height of wall
e	=	axial load eccentricity
D	=	depth of backfill
X_0	=	height of maximum moment = $D(1 - (D/3L)^{1/2})$
p	=	lateral soil pressure = $g\,\gamma_e$
W	=	resultant lateral load = $pD^2/2$
R_T	=	resultant force at top = $pD^3/6L$
R_B	=	resultant force at bottom = $(pD^2/6L)(3L - D)$
M_{X0}	=	maximum moment = $R_BX_0 - pDX_0^2/2 + pX_0^3/6$
P_A	=	axial load less brick fascia
P_B	=	weight of brick fascia
e'	=	equivalent eccentricity = $(P_A\,e + P_B(75))/(P_A + P_B)$
δ_b	=	moment magnifier = $1/(1 - (P_A + P_B)/.65P_C)$
P_C	=	critical buckling load = $\pi^2EI/(kL)^2$
E	=	modulus of elasticity = $5{,}000\sqrt{fc'}$
I	=	moment of inertia = $bh^3/12$
k	=	effective length factor = 1
f_c'	=	compressive strength of concrete
γ_e	=	equivalent fluid density of soil
g	=	gravitational constant (9.81 m/sec^2)
b	=	one metre of wall width

Table 2. Reinforcing Required for Walls to Perform Strengthwise Similar to a 200 mm Unreinforced Wall

Thickness of Wall	Reinforcing
100	10M @ 250
125	10M @ 375
150	10M @ 450
175	10M @ 525

Table 3. Vertical loads on foundation wall from a "standard' 2 storey house (kN/m) (used for Fig. 5, 6 and 7; reproduced in part from Ref. 8)

Item	2 Storey House	2 Story House with Brick Veneer
Dead Loads:		
Roof Shingled	1.20	1.20
Soffit, Facia	0.04	0.04
Ceiling	0.70	0.70
First Floor	0.61	0.61
Second Floor	0.61	0.61
Exterior Wall	1.31	10.21
Partitions	0.20	0.40
Live Loads:		
First Floor	4.56	4.56
Second Floor	3.36	3.36
Roof (snow)	12.40	12.40

Based on a house 9.60 m wide + 0.6 m overhang; live load 1.90 kPa first floor, 1.40 kPa second floor; ground snow load 2.87 kPa; a bearing line down the centre of the house supporting the first and second floor; roof trusses spanning 9.60 m.

Table 4. Cost Savings Thin Wall vs. Conventional (including 10% overhead and 10% profit)

	Lowest (Calgary)	Average	Highest (Grande Prairie)
Small House:			
Cost Diff. 15/125 to 20/200	$ 732	$ 896	$1,078
% Difference	8.6	9.9	10.8
Cost Diff 20/150 to 20/200	$ 400	$ 506	$ 611
% Difference	4.7	5.6	6.4
'Standard' House:			
Cost Diff. 15/125 to 20/200	$ 965	$1,193	$1,339
% Difference	8.9	10.3	11.1
Cost Diff. 20/150 to 20/200	$ 502	$ 642	$ 763
% Difference	4.6	5.5	6.3

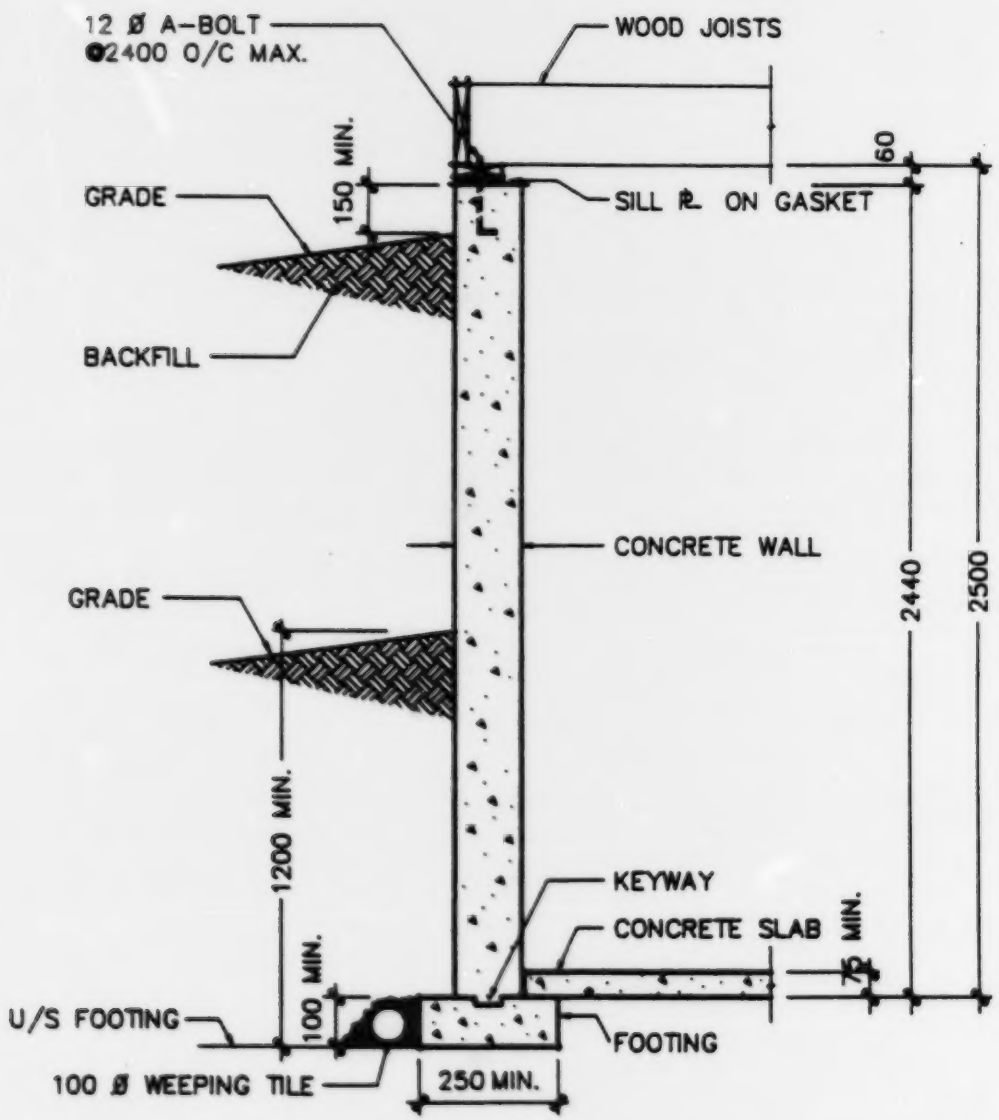

FIGURE 1 TYPICAL FOUNDATION WALL

9.15.4.1 Where average stable soils are encountered, the thickness of foundation walls subject to lateral earth pressure shall conform to Table 9.15.4.A for walls not exceeding 2.5 m in unsupported height.

Table 9.15.4.A: Forming Part of Article 9.15.4.1

Thickness of Foundation Walls			
		Maximum Height of Finish Outside Ground Above Basement Floor or Inside Ground	
Type of Foundation Wall	Minimum Wall Thickness mm	Foundation Wall Laterally Unsupported at the Top m	Foundation Wall Laterally Supported at the Top m
Solid concrete (14 MPa min. strength)	150 200 250 300	0.76 1.22 1.37 1.52	1.52 2.13 2.29 2.29
Solid concrete (200 MPa min strength)	150 200 250 300	0.76 1.22 1.37 1.52	1.83 2.29 12.29 2.29
Unit masonry	140 190 240 290	0.61 0.91 1.22 1.37	0.61 1.22 1.83 2.13
Column 1	2	3	4

FIGURE 2 ALBERTA BUILDING CODE 1985 REQUIREMENTS

Table IX Minimum thickness of foundation walls in average stable soil and for an unsupported weight not exceeding 8 feet

Thickness of Foundation Walls			
		Maximum Height of Finish Grade Above Basement Floor or Inside Grade	
Type of Foundation Wall	Minimum Wall Thickness in.	Foundation Wall Laterally Unsupported at the Top	Foundation Wall Laterally Supported at the Top
Solid concrete	6 8 10 12	2 ft. 6 in. 3 ft. 3 ft. 6 in. 4 ft.	5 ft. 7 ft. 7 ft. 6 in. 7 ft. 6 in.
Solid concrete	6 8 10 12	2 ft. 2 ft. 6 in. 3 ft. 3 ft. 6 in.	2 ft. 4 ft. 6 ft. 7 ft.
Square edge flat bed stone	12	-	7 ft.
Rubble	16	-	7 ft.
Column 1	2	3	4

FIGURE 3. HISTORICAL CODE REQUIREMENTS (1962 HOUSING STANDARD)

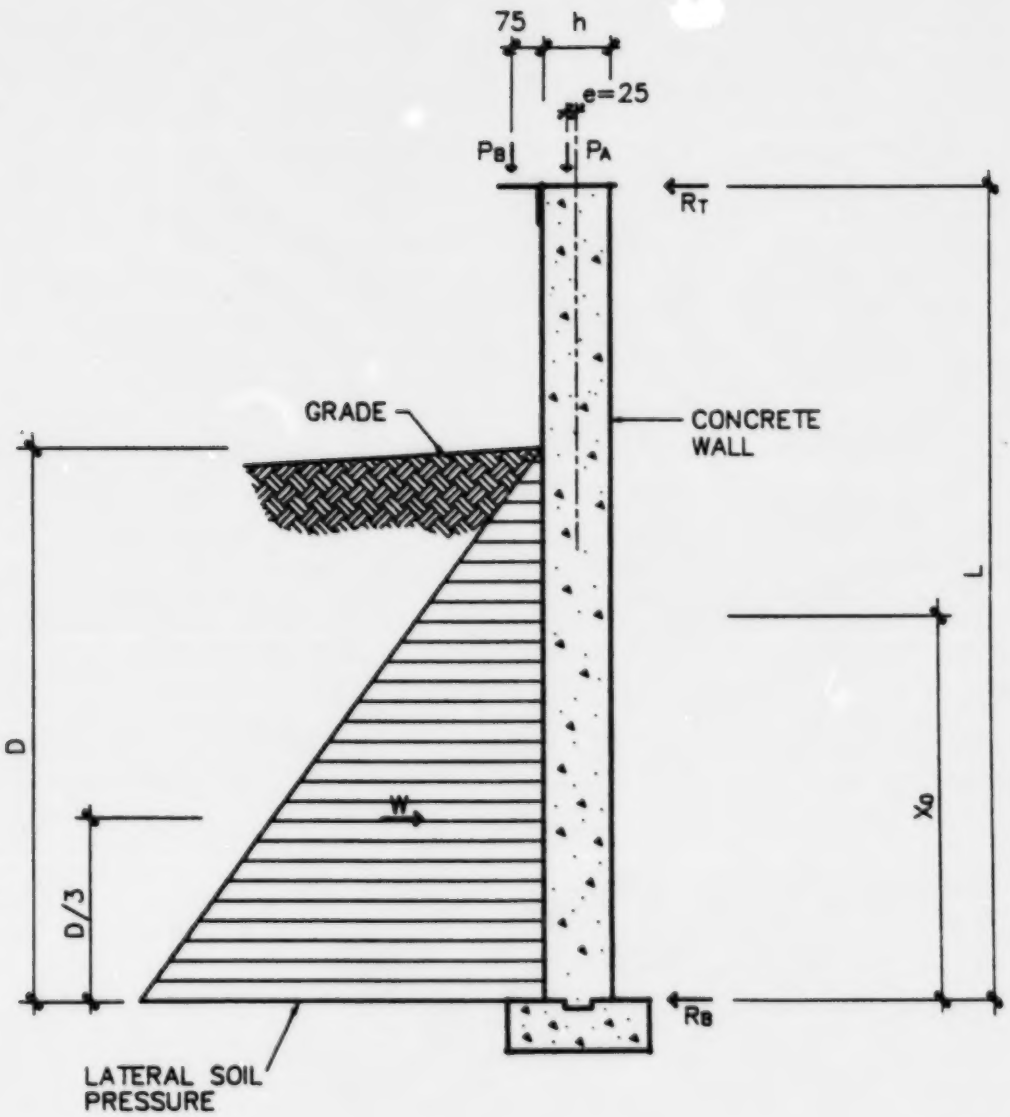

FIGURE 4 DESIGN MODEL

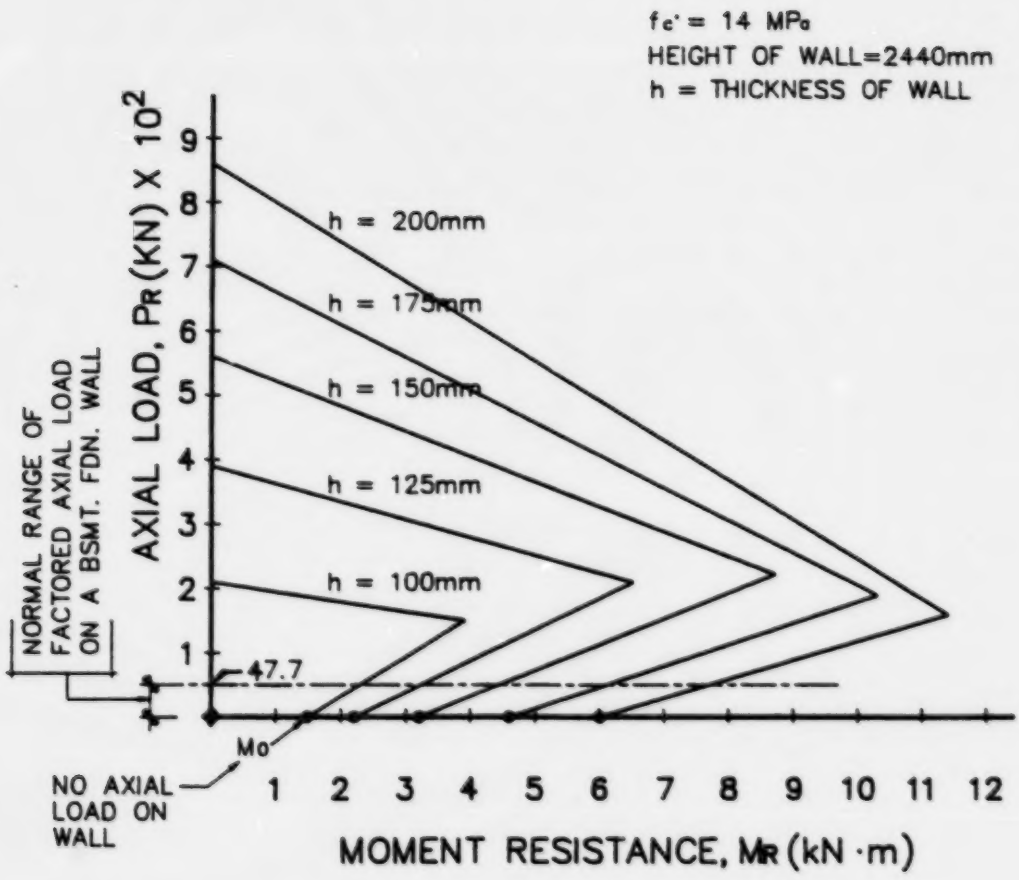

FIGURE 5 INTERACTION DIAGRAM FOR A 1 METER WIDE UNREINFORCED CONCRETE WALL

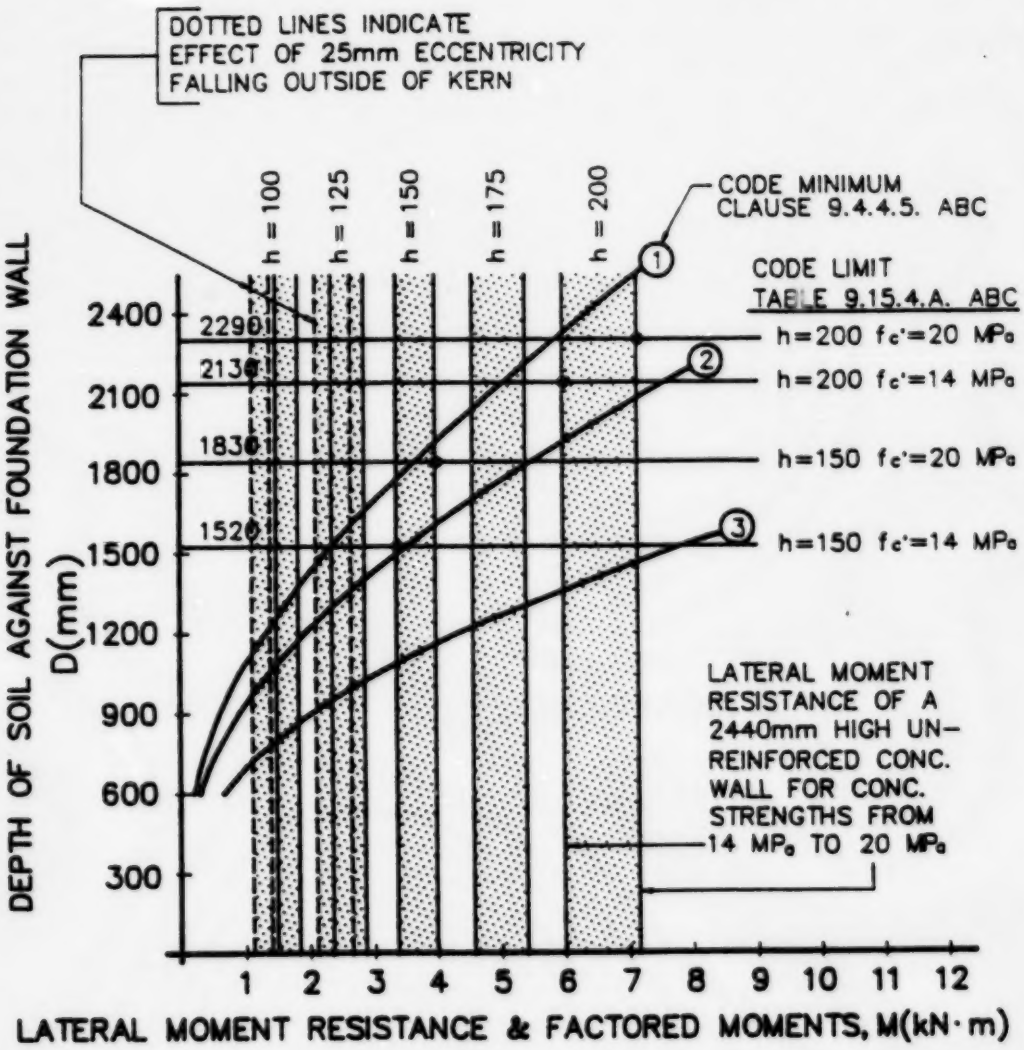

FIGURE 6 PERFORMANCE OF FOUNDATION WALLS WITHOUT BRICK VENEER

CIRCLED NUMBERS INDICATE FACTORED MOMENTS (α_L=1.5) ON A 2440mm HIGH WALL FROM THE FOLLOWING SOIL TYPES:

① CLEAN SAND AND GRAVEL (γ_e =480 Kg/m^3)
② STIFF RESIDUAL SILTS AND CLAYS, SILTY FINE SANDS, CLAYEY SANDS AND GRAVELS (γ_e =720 Kg/m^3)
③ VERY SOFT TO SOFT CLAY, SILTY CLAY, ORGANIC SILT AND CLAY (γ_e =1600 Kg/m^3)

γ_e = EQUIVALENT FLUID DENSITY

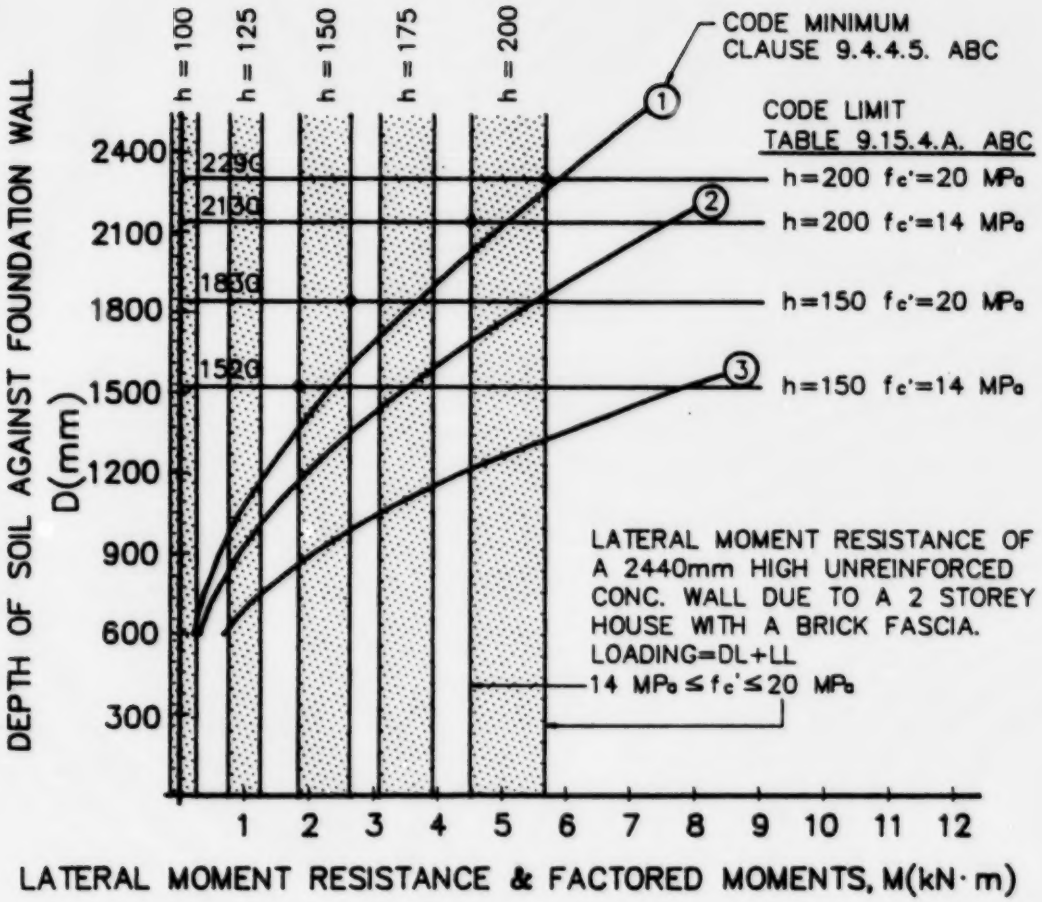

FIGURE 7 PERFORMANCE OF FOUNDATION WALLS WITH BRICK VENEER

FACTORED MOMENT OF SOILS TYPE ①, ②, AND ③ AGAINST A 2440 HIGH FOUNDATION WALL (SEE FIGURE 6)

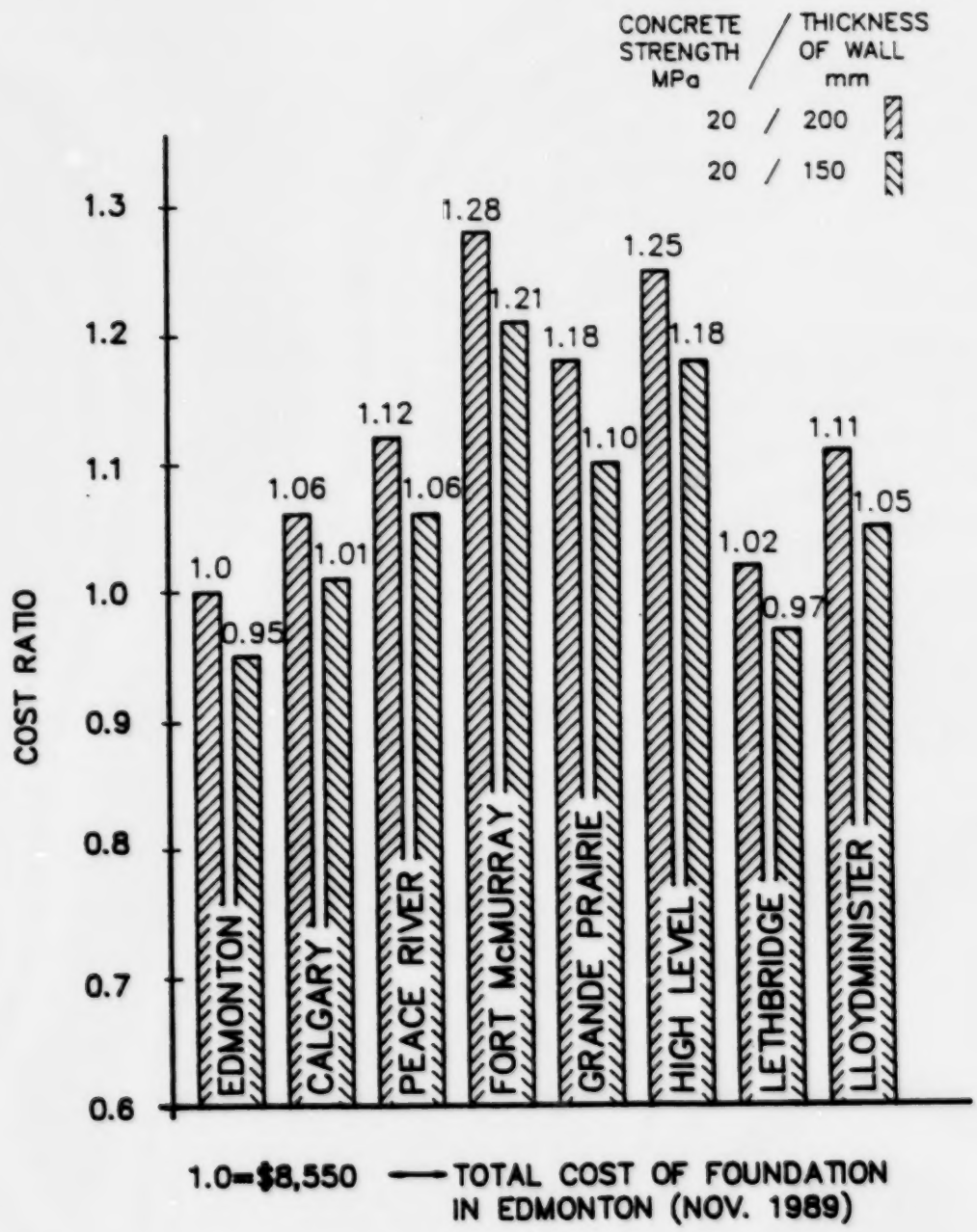

FIGURE 8 COMPARATIVE COST RATIOS

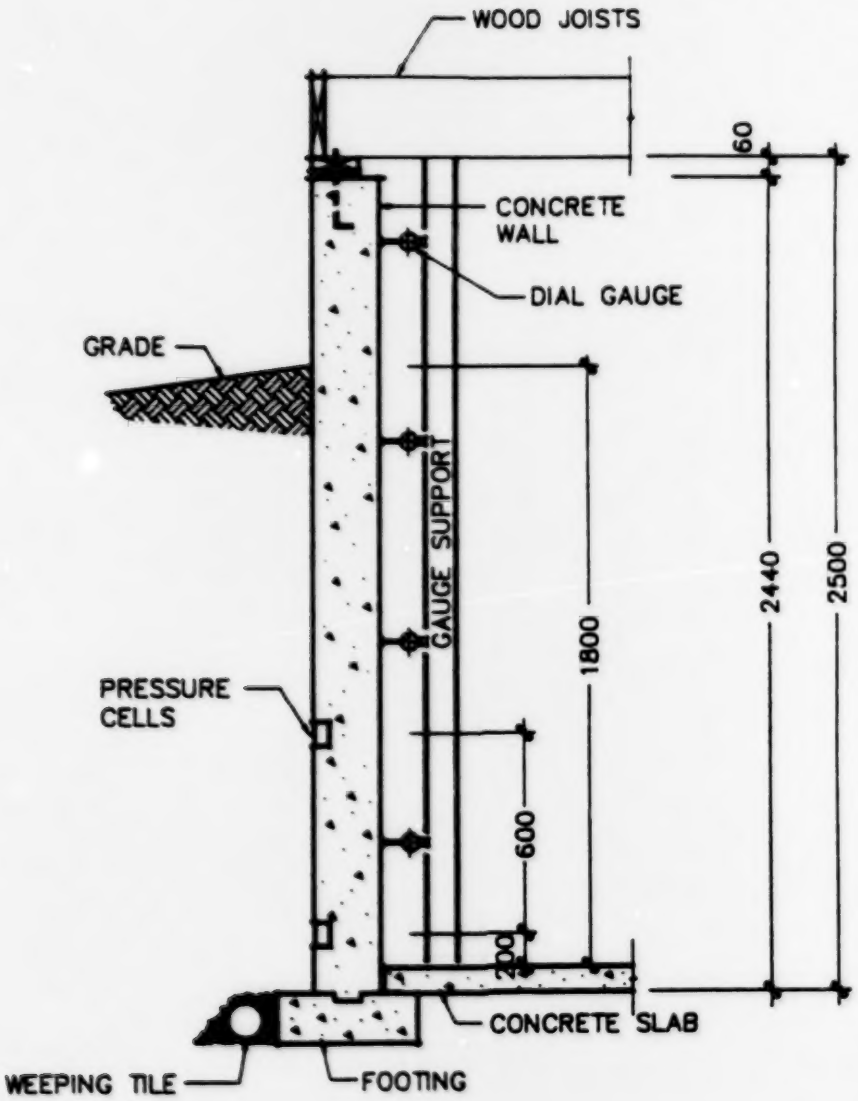

FIGURE 9 TEST WALL ARRANGEMENT

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APPENDIX 'A'

SUMMARY OF FINDINGS FOR THIN WALL FOUNDATION COSTS

Summary of Findings for Thinwall Foundation Costs

Comparative Cost Table								
Location	Edmonton	Calgary	Peace River	Fort McMurray	Grande Prairie	High Level	Lethbridge	Lloydminster
Small House								
15/125	$6,052	$6,465	$6,785	$7,711	$7,045	$7,560	$6,142	$6,577
15/150	6,219	6,621	6,988	7,954	7,286	7,796	6,307	6,784
15/175	6,386	6,776	7,192	8,197	7,527	8,032	6,473	6,991
15/200	6,553	6,931	7,395	8,440	7,768	8,268	6,638	7,198
20/125	6,170	6,575	6,880	7,805	7,131	7,634	6,272	6,756
20/150	6,349	6,742	7,093	8,058	7,385	7,878	6,454	6,982
20/175	6,529	6,908	7,307	8,282	7,639	8,121	6,631	7,208
20/200	6,708	7,075	7,492	8,535	7,894	8,365	6,811	7,434
Standard House								
15/125	7,690	8,258	8,647	9,839	8,950	9,629	7,841	8,396
15/150	7,941	8,491	8,952	10,204	9,312	9,983	8,089	8,707
15/175	8,108	8,646	9,155	10,447	9,553	10,219	8,255	8,914
15/200	8,358	8,879	9,461	10,811	9,914	10,572	8,503	9,224
20/125	7,837	8,394	8,764	9,956	9,049	9,721	8,004	8,618
20/150	8,106	8,644	9,085	10,335	9,430	10,087	8,273	8,952
20/175	8,286	8,811	9,298	10,588	9,685	10,330	8,452	9,183
20/200	8,555	9,062	9,619	10,968	10,066	10,969	8,721	9,522